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Biotic indicators for biodiversity and sustainable agriculture—introduction and background

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Abstract

The paper is an introduction to a volume containing 45 contributions on the development of biotic indicators for sustainable land use and biodiversity. It shows the background and origins of this particular issue as well as the motivation behind it. While a detailed subject-oriented synoptic introduction is provided at the beginning of each section [Agric. Ecosyst. Environ. 98 (2003) 35; Agric. Ecosyst. Environ. 98 (2003) 79; Agric. Ecosyst. Environ. 98 (2003) 255; Agric. Ecosyst. Environ. 98 (2003) 305; Agric. Ecosyst. Environ. 98 (2003) 407; Agric. Ecosyst. Environ. 98 (2003) 371], the intention of this contribution is rather to explain the general concept, the philosophy of the structure chosen, the understanding of important terms and the usefulness of the sections with regard to their content. It therefore serves the reader with a tool to understand this special issue as a whole. The volume is divided into sections "Requirements", "Biodiversity and Habitat" (including "Soil" as a subsection), "Biodiversity and Landscape", "Experiences and Application" and "Economy". From a generic point of view a brief survey is provided on the aspects and their relative backgrounds in each section, and completed by critical comments and conclusions, particularly regarding putting the theory into practice.

Keywords: Biotic indicator; Agri-environment; Assessment; Landscape; Habitat; Application

1. Background and starting point

At international level, a current need for criteria to assess the importance of land use for the preservation of the cultural landscape exists. Regardless of the fact that the increasing land use 1000 years ago was fundamental for the development of a high level of species biodiversity in Central Europe (Piorr, 2003), current land use techniques are said to be responsible for a loss of biodiversity. During the meetings in Cardiff (June 1998) and Vienna (December 1998) the European Council underlined the importance of the development of agri-environmental indicators. Such catalogues dealing with "Criteria for Sustainability" (CSD-indicators according to the Agenda 21) or "agri-environmental indicators" are currently being discussed or have recently been developed (OECD, 2000) respectively. In spite of the great number of indicators proposed (CSD: 134; OECD: ≈250), extraordinary deficiencies exist in particular for finding indicators for biotic aspects (Mannis, 1996; Commission of the European Communities, 1998, 2000).

Starting from this recognition, an initiative for a symposium (finding of indicators for a sustainable land use in the areas landscape and biodiversity) was taken by the working group "Agroecology" of the international "Society for Ecology" in Germany, organised and co-ordinated by a group whose members mainly consisted of the collators of the sections of this special issue (Büchs, 2003a). The majority of publications within this special issue originate from contri-

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butions presented at a 4-day meeting in a monastery at Freising, but were continuously adapted to the current status of discussions and completed by additional invited papers on aspects not covered deeply enough at the meeting.

It became obvious at how many Central European institutions the development of biotic indicators and questions on biodiversity in agricultural landscapes were focused on, and the partly completely different approaches made. In this regard, the need for discussions, and particularly the compilation of discussions, also became clear. However, nearly all working groups were moved by the question: How can very complex and widely differentiated scientific findings be converted into parameters that are easy to assess and which are suitable to be used as indicators for sustainable land use or biodiversity aspects? What are the options for assessing the "success" of measures that are implemented into agricultural practice in order to achieve a land use featuring maximum care of natural resources with regards to the desirable composition of species by easy, but reliable criteria?

2. Goals and open questions

The key issue of this volume is not "test organisms" as indicators for toxicological assessments mostly conducted under laboratory conditions, as they are commonly used within the registration procedure of pesticides or chemicals in general (e.g. Hassan et al., 1985, 1994; Commission of the European Communities, 1991). The goal is to find biotic indicators which enable the assessment of complex events occurring in agro-ecosystems under field conditions induced by husbandry practices and land use in general. One goal of this special issue is to contribute to the development of a strategy on how the assessment of biotic aspects in agro-ecosystems with the help of indicators can be handled and how these findings can be transferred to national as well as international panels and finally into practice. Within this scenario the role of science was defined to underlay the breakdown of goals that have been discussed and established by international committees (e.g. OECD, EU-Commission; World Trade Organisation) on a global level, to the landscape level, to individual farm level and last but not least to individual field level with scientific reliable facts. With reference to these goals the following headings were identified and forwarded to the authors to be considered within their contributions as far as possible:

- General/political requirements with respect to indicators.
- A survey of existing approaches.
- Transferability of biotic indicators (up- and down-scaling).
- Segregative or integrative approaches with respect to the application of indicators.
- Definition of hierarchic levels (priorities, ranking or "value" of indicators).
- Competing goals, risks of redundant evaluation using indicators.
- Requirements for validation, universal validity, potential of converting indicators into practice.
- Approaches of reimbursement and integration into farm economics.

With regard to the development of agri-environmental indicators, statements made by the EU-Commission to the Council of the European Parliament, by the Committee for Economics, the Committee of Social Affairs and the Committee for the Regions on 19 June 1999 pointed out that approaches which focus on single aspects will not consider the complex interrelations between agriculture and the environment. Beyond that, it was claimed for ecosystem-related approaches in order to consider positive or negative environmental effects in their entirety. In this regard the spatial indications of agri-environmental indicators should be developed from a concept of "landscape" as a partly seminatural cultural area, in which land use is practised and which is determined by the entirety of its biophysical and cultural features (Commission of the European Communities, 2000).

On the other hand the EU-Commission complains deficiencies of a spatial and thematic differentiation of agri-environmental indicators. The EU-Commission states that general and integrative indicators are available much more readily, but they provide only little evidence on the success of certain measures applied in agricultural practice. The EU-Commission judges indicators only as appropriate and effective if the conditions at a defined location can be considered, by using data which provide a clear specific and spatial differentiation (Commission of the European Communities, 2000).

Derived from the background described this volume compiles papers which cover the following topics:

- Political requirements and statements on biotic agri-environmental indicators.
- Requirements regarding agri-environmental indicators from a scientific as well as an applied point of view.
- Practical experience with the application and suitability of agri-environmental indicators (as far as they are already established).
- Scientific reviews and critical discussions of “state of the art” knowledge regarding several kinds of agri-environmental indicators for biodiversity and/or sustainable agriculture.
- Conceptions and models to show the economic effects and possibilities of practical application of such indicators.
- Original experiments on certain aspects regarding the indication of biodiversity in agro-ecosystems.

The following aspects were identified in detail for a discussion.

2.1. General

- A compilation of existing indicators which are practicable and based on the established knowledge of functions and power of agro-ecosystems.
- Identification of potential indicators free from existing demands on validation and practicability.
- Evaluation of the potential of applications, the practicability and transferability of existing indicators and new approaches of indication.
- Presentation and discussion of threshold values and reference values with regards to established indicators which are estimated as appropriate for applying in practice.
- Evaluation of the problems regarding the practical use of biotic indicators with regard to the power of scientific significance, efforts of surveying and of putting them into practice.
- Identification of the need for research, joint experiments, data survey, etc.

2.2. Requirements

- Requirements regarding indicators according to the OECD, or within the framework of CBD—“Convention of Biodiversity Development” (Agenda 21, United Nations, 1992), definition of agri-environmental indicators according to the international standard (International Standardisation Organisation, 1996) ISO 14001.
- Functional requirements and basic conditions, for instance according to the OECD, according to different professional authorities belonging to different administrative levels (e.g. federal republic, state, county or district local authority) and according to farmers. Which indicator is suitable for which purpose and for which user?
- Discussion of the problem concerning concrete evidence of a direct correlation between abiotic indicators as steering factors for determining biodiversity and the quality of the species set concerned.
- Suitability of indirect indicators as for example landscape parameters (e.g. percentage of hedgerows, field margins, etc.) as surrogates for complex biotic indicators.

2.3. Assignment of biotic indicators to different spatial units

- For which spatial level or administrative unit (e.g. EU, federal state, county, region, farm, field, natural unit, management form) can suitable approaches for a practicable (biotic) indication be defined?
- Discrepancy between the demands for the exactness of indicators at different spatial levels (global level versus ecosystem level).
- Is an upscaling, i.e. an accumulation of results derived from surveys by indicators at lower spatial levels possible?

2.4. Survey, validation and power of statements

- Possibilities and modalities of a standardisation of the survey methods.
- Validation and scientific evidence of indicators (gaps, problems, possible solutions).
- Capability of representation (e.g. transferability from one to another biological taxon).
- Problems and possibilities of simplifications to biotic indicators in respect to their power of scientific evidence.
- Problems of data aggregation: How can data losses be avoided or handled?

- The amount of time and money required for surveys in order to achieve a statistically sufficient sample size.
- Frequency in time, extent and intensity according to which a survey of indicators should be repeated.
- Capability for modelling with respect to the adaptation to field conditions and practical demands.
- Designation of competence with respect to the qualification level: Who should be allowed to survey indicators and to convert the conclusions drawn from assessment results?

2.5. Assessment procedures

- How do indicators become assessment tools?
- What is the basic level for assessment (e.g. baseline reference values)?
- Who defines baseline reference values, thresholds, limits? To which criteria will they be linked?
- Are these values fixed as absolute or as relative values? How are they related to regional conditions?
- What are the goals? The achievement of which ecosystem features can be checked by biotic indicators?
- Scale levels: Should only indicators of the same spatial scale level be considered in an assessment procedure?
- Overlapping and competition of different biotic indicators in their areas of competence: are redundancies and/or double assessments (carried out by different indicator approaches) senseless or do they enhance scientific evidence?
- Weighting of indicators within complex assessment systems: Establishment of priorities only within comprehensible sections and preconditioning of goals?

2.6. Communication

- Problem of communication between different levels dealing with indicators and assessment procedures (pure research $\Rightarrow$ applied research $\Rightarrow$ institutions managing conversion into practice $\Rightarrow$ political decision makers $\Rightarrow$ users).

3. Glossary definitions

The title and sections chosen for this volume contain terms such as “biotic indicator” or “bio-indicator”, “sustainable agriculture/land use”, “biodiversity”, “habitat” and “landscape” which raise expectations for definitions in order to provide a clear understanding. However, the intention of this volume is not to go into detail about discussing terms; thus, only some basic and more or less well established definitions are provided, which should fulfil the intention of this volume as far as possible. A more extensive discussion of the key terms “indicator”, “biodiversity” and “landscape” can be found in the synoptic introductions to the individual sections (Büchs, 2003b; Waldhardt, 2003; Osinski et al., 2003).

3.1. Indicator

With regard to the term biotic indicator or bio-indicator and its potential and limits, an intensive and fundamental discussion took place at the beginning of the 1980s (e.g. Arndt et al., 1987; Bick, 1982; Phillipson, 1983). However, at that time the discussion was not related to agro-ecosystems, but had its origins in the discussions on forest damage due to air pollution and the environmental impact of nuclear plants. Nevertheless, the fundamental principles can be completely transferred to biotic indicators applied in agro-ecosystems.

Similar to chemical reactions, which result in clear and unambiguous effects indicating the current status of a fluid solution or the end of a (chemical) reaction if a very small amount of an indicator substance is added, are also the requirements for a biotic indicator with respect to the characterisation of the current status (status indicators) or ongoing processes (process indicators) within ecosystems: the indicator substance is replaced by a biotic indicator (e.g. a species [community]/population/organism) that in ideal cases represents the biocoenosis to a certain extent and provides information of status and/or on changes of the ecosystem compartment considered (Büchs, 1988). However, at the time in question, a biotic indicator was mainly interpreted as an organism that reacts to harmful substances (e.g. heavy metals, air pollutants, pesticides) by changing its life functions, e.g. metabolism (reaction indicator) or by accumulating substances (accumulation indicator). The understanding of biotic indicators was focused more in the sense of test organisms (for testing toxicological ef-

fects under standardised conditions in laboratory or semi-field experiments) or as "monitor species" (e.g. lichens) which are placed outside in the environment to detect factors such as air pollution (Arndt et al., 1987).

Biotic indicators or indication systems which provide information on the current status of, or processes going on in ecosystems were introduced at species level by Hesse (1924), and Kühnelt (1943) and picked up again by Bick (1982), Dunger (1982), Kneitz (1983) and Phillipson (1983). According to Dunger (1982) and Phillipson (1983) the enlisting of single species/populations is only partially appropriate for a biotic indication because of a very limited representative value. Only if complete species assemblages or ecosystem-related taxocoenosis are included in indicator systems is the power of statements considerably increased compared to single species. Perner (2003) showed that the relation of the level of precision to required sample size (number of samples required to achieve a tolerable variance regarding data) is less favourable for a selected indicator species but much better for community parameters such as species richness, and particularly evenness, so that—within the assessment of biotic indicators—community-related indicators should be preferred to species-related parameters.

Often, species communities are very strictly correlated to certain environmental conditions so that they can be used for indication (e.g. Ellenberg et al., 1992; Büchs, 1995). "Indicator communities" can be identified (Bick, 1982), which give an indication of the intensity of certain impact factors and their combinations through presence or absence of species or the changing of dominance positions. In principal, within this context each species can be used as an indicator, but the importance of stenoecious species (species closely adapted to certain biotic/abiotic conditions) has to be particularly emphasised, since they are usually more effective indicators than euryoecious species (see Döring and Kromp, 2003; Döring et al., 2003; Nickel and Hildebrandt, 2003; Perner and Malt, 2003).

The Organisation for Economic Co-operation and Development (OECD), which has developed agri-environmental indicators in 13 different areas (e.g. biodiversity, wildlife habitats, landscape, farm management, pesticide use, nutrient use, water use, soil quality, greenhouse gases, socio-cultural issues, farm financial resources; OECD, 1999, 2000) favours the Driving Force-State-Response framework as a basic principal:

- *Driving force*: What is causing the environmental conditions to change?
- *State*: What are the effects on the environment?
- *Response*: What actions are being taken in public and private sectors to respond to changes in the state of the environment?

This three-step concept which combines the analysis of causes, effects and countermeasures to "repair" negative effects is to a certain extent reflected in the structure of this volume: particularly in section "Habitat", the development of indicators and their validation is usually based on the effects (*state*) of different husbandry practices which are the *driving forces*. Sections "Experience and Applications" and in particular "Economy" include approaches to manage changes in the environment (*response*). However, with regard to finding and developing indicators, the main focus of this volume will be the measurement and assessment of the current *state* and of developmental trends regarding environmental and natural resources in agricultural systems.

The Commission of the European Communities (2000) defines 'agri-environmental indicators' as a "generic term designating a range of indicators aiming at giving synthesised information on complex interactions between agriculture and environment. Common agri-environmental indicators are those that provide an assessment of impacts of agriculture on water quality, climate change, soil, or landscape structures". The fact that the term biodiversity is not mentioned in this definition shows how difficult this term is to tackle (see Büchs, 2003b; Büchs et al., 2003).

3.2. Sustainable agriculture

"Sustainability" (European Commission, 1998), "sustainable development" and so "sustainable agriculture" are terms that tend to be diluted and in consequence easily "abused" as it is also the case of the term "integrated" (integrated crop production, integrated pest management, etc.), due to the lack of clearly defined criteria and limitations. The World

Commission on Environment and Development defined “sustainable development” as “development which meets the needs of the present without compromising the ability of future generations to meet their own needs” (Legg, 1999). However, by the mid-1990s, there were well over 100 definitions. To avoid adding to this confusion, here a very basic definition by Stinner and House (1990) is used: sustainable agriculture (a) conserves the resources on which it depends; (b) restricts itself to a minimum input of production means, which do not have their origin in the same farming system; (c) controls pests and diseases by internal regulation processes as far as possible; (d) provides natural resources with the ability to recover from disturbances through cultivation means and harvesting by processes of natural succession. Sustainable farming requires intensive management and substantial knowledge of ecological processes.

3.3. Habitat

This is simply known as the place or type of site where an organism or population occurs naturally. The habitat of a (plant or animal) species is its “place of residence”, that means the region to which it is adapted and which it is able to occupy. This does not mean so much a concrete habitat, as a habitat type including specific factors (ecological conditions) which allow the species to survive and to reproduce successfully. If the habitat quality changes (e.g. due to anthropogenic impact) or the ecological requirements of the species change, it is forced to retreat from its place of residence (Odum, 1980).

3.4. Landscape

Regarding the term landscape the European Commission (2000) admits the complexity of this term as a concept encompassing several definitions. On a higher scale level the term landscape as “an area containing a mosaic of land cover patches” (area units, covered by a single class of land cover or habitat) is adopted as a key definition. Particularly at higher scale levels and/or in planning procedures “mostly only a two-dimensional spatial configuration is considered and its influence on the landscape physiognomy, but not the vertical dimension and its effects on abiotic as well as biotic factors and visual perceptions”. The term landscape is narrowly linked to the term land use which reflects the “functional dimension” of the socio-economic situation in a region (European Commission, 2000). However, especially in relation to the assessment of landscapes, the problem is that the purpose of land use (e.g. whether land use serves for agricultural, recreational or conservation purposes) is often not clearly defined and so may influence the development of classification systems, data collection, the use of (biotic) indicators and finally the assessment system in general.

4. Philosophy of structure and focus as regards contents

Aspects dealt with within this special issue on “biotic indicators for a sustainable land use” in order to provide biodiversity are considered more from an applied point of view than a scientific point of view. Reflections on a logical structure covering relevant areas led to a subdivision into the five sections “Requirements”, “Biodiversity and Habitat” (including “Soil” as a subsection), “Biodiversity and Landscape”, “Experiences and Applications” and “Economy”, which is explained in the following.

Starting with the presentation of (political) requirements (Piorr, 2003) the structure of this volume is arranged in a kind of “bottom-up-approach”, i.e. the analysis of smaller compartments in agro-ecosystems (habitat-components) is followed by the consideration of larger spatial units, the landscape level, and finally completed by existing experiences with the application of (biotic) indicators and economic impacts.

In section “Requirements” the (political) demands of committees and institutions authorised to put indicators into practice and into political frameworks at national and international levels are placed at the front of the volume. The philosophy of those committees can be demonstrated by, for example, the self-description of the OECD: “OECD work on agri-environmental indicators (AEIs) is primarily aimed at policy makers and the wider public interested in the development, trends and use of agri-environmental indicators for policy purposes. The focus of the work is in particular related to indicator definitions, methodologies and calculation of indicators”. This includes the following general objectives:

- Provide information on the current state and changes in the conditions of the environment in agriculture.
- Assist policy makers in a better understanding of the links between causes and impact in agriculture and agricultural policies.
- Reform trade liberalisation and environmental measures, and help to guide responses for changing environmental conditions.
- Contribute to monitoring and evaluating the effectiveness of policies addressing agri-environmental concerns and promoting sustainable agriculture, including future-oriented perspectives of agri-environmental linkages (OECD, 2000).

Politically the following basic *requirements* are considered for the development of biotic agri-environmental indicators (L. Nellinger, Federal German Ministry for Customer Affairs, Food and Agriculture, Bonn; in litteris, 2001): (1) scientific soundness; (2) adequacy of goals; (3) political relevance; (4) comprehensibility; (5) communicability; (6) balance.

Regarding the term "*scientific soundness*", political decision makers *do not* understand a successful validation and statistical significance of messages from biotic indicators, but rather, wherever possible, the adaptation of agri-environmental indicators to environmental problems or positive environmental performances related to husbandry practices. Therefore, "scientific soundness" mainly refers to the position of an indicator within the complete set of existing indicators. This aspect also covers the avoidance of redundancies and the implementation of interfaces to other society-related information and documentation systems, as for example the environmental-economic balance sheet.

"*Adequacy of goals*" means that with indicators, the degree of fulfilment of environmental political goals should be measurable. Indicators which may be highly sophisticated from a scientific point of view, but whose message is inadequately linked to goals of environmental politics, carry a considerable risk of political mistakes.

"*Relevance for political action*" means that conditions reflected by the indicators should provide the ability to be influenced by political decisions and related adaptations by producers and consumers.

Because the great majority of decision makers (e.g. politicians, parliamentarians, journalists and ordinary citizens) are not scientifically educated, the indicators and the criteria they are based upon must be *comprehensible*, so that *communication* is possible. Even this basic criterion is often not fulfilled by scientifically excellent indicators.

To avoid mistakes in steering political processes biotic indicators should be *balanced* sectorally (i.e. regarding the different environmental problems and performances of agriculture/land use) as well as intersectorally (regarding interactions between different branches of business and the international comparison of the environmental situation in different countries). To achieve this *balance* the existence of *supraordinate evaluation scales* and *standardised report systems* are necessary.

The (political) benefit of an indicator increases if these basic demands are fulfilled, and all the more if they are accepted within international regulations. An overall precondition is a reasonable cost/benefit-relation in the case of putting the demands into practice.

These political demands elucidate that in international negotiations on indicator systems, global acting indicators with a comparatively general and almost "weak and rough" message are discussed as a priority. These indicators are able to detect (environmental) impacts or positive performances of husbandry only on a very general level in order to make efforts for international solutions and/or regulations compatible.

At international level (e.g. OECD, 2000), particularly indicators for abiotic measures have reached a high standard, and for many of them, a more or less complete series of data from nearly all Member States already exists. Indicators however, that aim to assess biodiversity and landscape matters, have reached not more than a proposal stage, and are beginning to be tested as models.

An example of the kind of indicators recently used and/or proposed at international level (e.g. by the OECD) and the way they are used are the so called "contextual indicators" (Piorr, 2003). Within the topic "farm management and the environment", information has been gathered about, e.g. "environmental whole farm management plans", "nutrient management plans", "conducting of soil tests", the "use of non-chemical and/or integrated pest control methods",

"soil cover" and "land management practices". Within the topic biodiversity, information on genetic diversity is predominantly asked for, as for instance "registered number of crop varieties", "registered number of livestock breeds", "share of key crop varieties", "share of key livestock breeds" and "number of endangered crop varieties and livestock breed". With regard to species diversity, the analysis is restricted to "wildlife species on agricultural land" and "non-native species threatening agricultural production". Therefore, apart from some (vertebrate) game species and (probably mostly invertebrate) invaders, no information on the indigenous fauna and flora typical for agricultural areas (which is represented by far more than 1000 species) has to be provided to assess biodiversity!

Piorr (2003) also points out a considerable lack of reliable and consistent data, even at a supraordinate level: the result of a questionnaire among 15 European states showed that on average, 75% of the information for each category was lacking. Only statistically correct records can be provided for organic farming, even for marketing cultivars or the status of endangered livestock breeds, due to strict criteria and controls. In all other areas (with regard to conventional farming) the consistence of data is very deficient and not standardised.

Negotiations at international levels have brought another key problem to light: states that cover large areas and rely on a relatively short time of history (with regard to the recent majority of inhabitants) as for example the USA, Canada or Australia, show a completely different understanding of the term landscape. Based on large geographical units they divide strictly between landscapes for (agricultural and industrial) production and landscapes for nature conservation (H. Becker, Berlin, personal communication, 2001). This understanding which puts a lot of different ecosystems together in each category reacts upon the features of indicators which are rather coarse because a very low level of differentiation is needed. These highly globalised and generalised indicators which have recently formed the basis of international approaches for agri-environmental indications, result in unavoidable and considerable losses of information. Information derived from such indicators might be useful on the level of supraordinal landscape units, but their conversion to a single farm will be problematic.

Therefore, these kind of indicators are not transferable to rural landscapes in Europe because of completely different initial conditions: the cultural (and agriculturally used) landscapes in Europe have been developed historically over almost a 1000 years, so that particularly those where traditional structures are still present today can be judged as "cultural objects" in a very similar way to buildings (e.g. castles, towers, etc.) that create a regional identity (e.g. UNESCO Cultural Heritages of the World). In these traditionally grown cultural landscapes production, recreation and nature conservation cannot be separated but are intensively linked to each other within the same region and geographical unit. Following today's understanding in Europe, particularly the cultivation of landscapes was one of the main reasons for creating new habitats for plants and animals and so it was the most important source for an increasing biodiversity.

These basic differences derived from geographical conditions; the historical-cultural development of different countries has recently become increasingly acceptable in international negotiations on agri-environmental indicators (e.g. OECD, 2001). This means that recently, a more sensitive understanding has led to turning away from average values on a national basis and considering more seriously regional characteristics, which can be identified by special features of natural resources and regional cultural development.

Nevertheless, compared to the great number of scientifically very interesting and sound approaches regarding the development of very sensitive indicator systems, which potentially enable the exact measurement and assessment of the environmental status very exactly on several scales for single compartments of ecosystems or habitats, and for several taxa (Albrecht, 2003; Waldhardt et al., 2003; Büchs, 2003b), there is obviously a huge discrepancy between the latter and demands at international level. One solution (regarding the use of highly aggregated indicators that fulfil the demands at international level, but based on a not aggregated substructure) could perhaps to integrate them into regional agri-environmental programmes which would become more efficient through this linking.

In the context of the term *habitat* indicators and indication approaches are summarised that refer to single, clearly defined habitats within rural landscapes. In

this regard the focus is clearly put on cultivated areas (e.g. fields, grasslands, orchards, vineyards, etc.). In some papers within-field structures (Brose, 2003) and uncultivated marginal structures are also considered as far as they produce interactions with the cropped areas. Furthermore, larger uncultivated areas (e.g. fallow land) which are identified as reference areas from which standards for an assessment by means of indicators can be derived (e.g. Büchs et al., 2003; Döring and Kromp, 2003; Irmler, 2003; Jeanneret et al., 2003; Perner, 2003). On the other hand, indicator concepts were also summarised in the context of the term *habitat* that refer to features of populations of one or more species (e.g. body size, body weight, fertility, etc.), for determining whether cultivated areas (fields) are the preferred habitat for feeding, for reproduction activities and so on, and whether they are within the focus of the assessment goals (Büchs et al., 2003; Döring et al., 2003; Nickel and Hildebrandt, 2003). With regard to this topic, interrelations (e.g. seasonal migrations) with other (uncultivated) habitats at various distances to the field are likely to occur (e.g. within birds), so that transitions to landscape-related indication approaches cannot be excluded (e.g. Jeanneret et al., 2003).

Within the habitat-related analysis *soil* aspects have been separated (Anderson, 2003; Ekschmitt et al., 2003; Ruf et al., 2003; Schloter et al., 2003a,b) due to the following reasons:

- The soil is a more or less self-contained medium (except its surface), unless there is no doubt that processes occurring in the soil affect other compartments of the ecosystem (e.g. vegetation, crop microclimate) significantly.
- Soil biology requires a specific methodology and terminology, which also react upon approaches to develop indicator systems.
- Processes within the soil are often slower and more sustainable (e.g. changes which are detectable rather in the long term) than in other compartments of an ecosystem; so they are to a less extent characterised by short-term invasions and emigrations. This phenomenon requires adopted indication concepts.
- As a consequence of remineralisation processes within the soil, adhesion and the release of substances, the building of aggregates, etc., the soil compartment has a stronger and more direct relation to abiotic conditions which possibly requires specific procedures of indication.

The broad range of taxa which should be considered and the requirements regarding a sufficient number of samples (which in many cases is not realistic) are the key problems for a conversion of habitat- and biodiversity-related indicator approaches into practice (Perner, 2003). An exception might be plant species that are easy to determine (Oppermann, 2003). In soil microbiology this problem is not so obvious because up to now, non-taxa-specific, but summarising parameters have been used (e.g. *C*/*N*-relation; Anderson, 2003). However, with increasing possibilities of the characterisation of microorganism communities (quasi-species levels and ecological types) as introduced by Schloter et al., 2003a,b, one has to be aware that soil microbiology is probably approaching a similar dilemma to the one we are currently facing concerning surveys of invertebrate communities in particular (Duelli and Obrist, 2003). Therefore, indicators based on population and/or on habitat features have more the function of providing the fundament for indicators or indication systems, which act in a far more indirect way, a fact derived from practical experience, established knowledge and/or logical deductions (e.g. application of certain measures, enhancement of landscape elements or habitat developments are estimated to increase biodiversity) (Menge, 2003; Oppermann, 2003; Roth and Schwabe, 2003). Furthermore, they are available for detailed assessments (Büchs et al., 2003; Nickel and Hildebrandt, 2003; Mueckschel and Otte, 2003; Perner and Malt, 2003; Rosenthal, 2003; Gerowitt, 2003). Heyer et al. (2003) provided the missing link to show whether the surrogate indicators are scientifically reliable and the most appropriate manner for applying them. More details are discussed in the summarising synoptic introductions by Waldhardt et al. (2003), Büchs (2003b) and Schloter et al. (2003b).

Whenever the term *landscape* is the focus for developing suitable indicators, cultivated fields are analysed in relation to the surrounding types of habitats and ecosystems. Within the section "Landscape", several different scale levels can be the focus of analysis. The starting point for the development of indicators for *landscape* assessment can be the cultivated area itself as well as directly neighbouring habitat types

(or those within a defined distance), regardless of whether they are cultivated or not, and the combination of the two which forms the "landscape matrix" (Dauber et al., 2003; Hirsch et al., 2003; Steiner and Köhler, 2003; Waldhardt and Otte, 2003). Assessment can be related to the entire area of local farms (Richter et al., 1999), to functional units (e.g. bottom land meadows, heaths; see Osinski, 2003; Jeanneret et al., 2003), to regions that are defined by natural units (e.g. Hoffmann et al., 2003; Hoffmann and Greef, 2003; Osinski et al., 2003), to administrative units of different scale levels (Osinski et al., 2003) or to surveys fixed to standardised spatial grids (Hoffmann-Kroll et al., 2003). This listing demonstrates that the approaches to biodiversity indication at landscape scale level are rather heterogeneous. The different concepts show a very different potential towards both a regionalisation and a spatial aggregation of data. Even some attempts at indicator systems is presented in the "Habitat" section—if recorded over a wide area—have the potential of being put together to form larger spatial units and can thus be used for assessments at landscape level.

In some cases the term biodiversity which originates from genetical biodiversity and species biodiversity is used for landscape complexity (or landscape patchiness defined as richness of habitat and land use types), which are secondarily linked to the species richness of those ecosystems. On the other hand indicator approaches that are strictly focused (oriented) on the population development of individual species (e.g. "mosaic indicators" by Hoffmann and Greef, 2003) may form transitions to indicators that refer specifically to the habitat quality.

Therefore, the handling of information losses as an unavoidable consequence of data aggregations can be classified as one of the key issues of "Landscape" section. Spatio-temporal processes and interactions, which are extraordinary effective at landscape level due to the extremely variable performance of cultivated habitats within seasonal changes, also play an important role.

Particularly this factor raises the question regarding the function each ecosystem (or habitat) type has in respect to its contribution to and preservation of biodiversity at landscape level in space and time. In this context it is of particular interest to see how these functions, that underlie extremely complex seasonal changes, can be assessed and how they can be integrated into indicator systems. Further details of landscape-related assessment procedures are discussed by Waldhardt (2003).

Section "Experience and Application" shows ways and modalities of how assessment procedures that are already established, or are currently being developed, handle biodiversity evaluation. Therefore, analysis was strictly concentrated on biotic indicators. Considerable deficiencies regarding applicable biotic indicators were obvious from the start.

With the exception of a few procedures (e.g. Frieben, 1998; Oppermann, 2003; Buys, 1995; Oosterveld and Guldemond, 1999) the assessment of biotic parameters (as for example biodiversity) is not carried out directly (by actual on-site recording of organisms), but is mostly derived from parameters which are assumed to be correlated to biodiversity or other ecological features which are being focussed on. Several measurements or parameters (e.g. low extent of bare fallow, low input of pesticides, high percentage of landscape structural elements, margins and structures adjacent to fields, etc.) are treated as equivalent to positive biodiversity development (Braband et al., 2003; Menge, 2003; Roth and Schwabe, 2003). The legitimacy and "validation" of this kind of indication procedure is usually derived from information selected from published references. One of the major concerns of this procedure is that most of the published experiences are based on case studies with clearly defined conditions (with regard to farming system, on-farm structures, abiotic conditions such as soil, hydrology, climate, etc.) and so, often only correspond in a very limited way to the specific requirements of the indicator chosen.

Only exceptional naturally occurring organisms as for example conspicuous plant species, butterflies or vertebrates which can also be easily recognised by amateurs are used as indicators (e.g. Oppermann, 2003; Frieben, 1998; Buys, 1995; Oosterveld and Guldemond, 1999).

Assessment procedures are very limited due to costs and practicability, so that one has to assume that, as the recent status of technical development stands, biodiversity indication will in practice be conducted mainly by using indirect parameters or surrogates derived from published basic knowledge on biodiversity mat-

ters. This patching together of results involves the risk that biodiversity indication is inexact. Koehler (1999) points out that "underestimation of taxonomy threatens the whole idea of bio-indication, because it is not sufficient to identify *invertebrates* (changed by the author) up to higher taxonomic categories (genus or family); the correct determination of species is however an absolute prerequisite. It must be emphasised that biology, ecology and consequently indicator properties are strictly related to the species". In this context it has to be mentioned that for the assessment of fresh water, an international procedure exists (saprobia-index), which was established almost 100 years ago, and has been continuously developed since (Friedrich, 1990; Marten and Reusch, 1992; Usseglio-Polatera et al., 2000). This index can be used in a modular way, which includes the on-site survey of a broad range of organisms and which allows statements on biodiversity. Each water supply office has employed at least one specialist who is exclusively responsible for water quality assessments by using biotic indicators mostly on the species level. This raises not only the question of whether (or why not) corresponding possibilities exist for establishing a similar approach for terrestrial ecosystems, at least for those under cultivation, but also the question of which priorities are established for agri-environmental procedures with reference to assessing husbandry practices. Altogether a completely new dimension arises through the fact that world-wide, labels of certification are now being used by the food industry and the retailer co-operatives of several branches which aim to guarantee an environmentally friendly and socially conscious production of food (e.g. Euro-Retailer Produce Working Group, 2002; Flower Label Program, 2002; Forest Stewardship Council, 2000; Rainforest Alliance, 2002; Pan European Forest Certificate, 2002). With reference to the Convention of Rio (United Nations, 1992), such certification labels also pick up aspects of biodiversity and its indication, but with a poor scientific background similar to the agri-environmental assessment procedures mentioned above.

Against this background it can be assumed that in the future, maintenance and conservation of biodiversity will not only be ruled and controlled by governmental institutions, but as the consequence of general tendencies of globalisation, on the basis of "private initiatives" of trade associations by establishing various labels and quality seals. These approaches will be complemented by the implementation of environmental management systems with voluntary participation (EMAS I and II; European Community, 1993, 2001). These developments demonstrate that work on biotic indicators is no longer merely a scientific end in itself, but that certain groups of society need practicable (biotic) indicators; this need has long since overtaken the current status of discussion within the scientific community.

The volume is completed with the consideration of *economical aspects* of biotic indicators. Although at first the development of biotic indicators occurred (and partially still does occur) completely separately to practical demands on a scientific level, the integration of economical aspects seems to be undeniable with respect to the key position of the economy as far as the possibilities of putting biotic indicators into practice are concerned, which finally also influences their development significantly.

Within the economic analysis, the cost-efficiency ratio of agri-environmental programmes and measures is assessed with respect to the improvement of biotic resources, by recording the success of the measures applied. Even in economics the biodiversity-related control of success (of measures applied) is not conducted directly, but indirectly for instance by specialist evidence (e.g. Marggraf, 2003), which is validated by recently developed methods of analysis as for example the Delphi-method (Richey et al., 1985).

Further aspects are strategies to integrate biodiversity-related goals into land use systems not only practically but also economically (Plachter and Werner, 1998). With reference to these aspects, parameters that are related to the production process are also considered, as for instance calculations and models of the disturbance potential (with reference to biotic resources) of different production systems, which are finally included in the entire farm-related economic calculation with the goal of developing a farm-related, economically optimised model on the basis of agreed environmental quality goals for the preservation and enhancement of biodiversity. In this regard, at the farm level the different management measures are incorporated into a field record system, from which potential conflicts with demands of nature conservation can be derived (Meyer-Aurich et al., 2003; Kantelhardt et al., 2003).

In a further step modelling techniques for the assessment of economic effects on the protection of biodiversity are tested by Herrmann et al. (2003) for different geographical scale levels. This advanced approach aims to integrate biotic indicators and control of success (of measures applied) in an optimised way into the operational course of the farm, taking into consideration economic aims. By means of "trade-off-functions" (loss of goal realisation) the level of goal achievement can be determined taking into account both economically and agriculturally based practical constraints which correspond to farm costs under the premise of agricultural production. In respect to these trade-off-functions, standard methods are tested as for instance the "Replacement Cost Method" (Pearce, 1993), the "Contingent Valuation Method" (Mitchell and Carson, 1989) and concepts such as "Save Minimum Standards" (SMS) and the "Precautionary Principle" (Meyer-Aurich et al., 2003).

Economic considerations include transaction costs, costs for information transfer regarding the control of the success of measures applied, and for the organisation and control of compensation payments. Another focus is the integration of non-tradable goods (in this respect: biotic resources) into a cost-benefit-analysis, which means money as an indicator for rational decision-making on biodiversity conservation (Bräuer, 2003). The idea is that the estimation of the (economic and social) benefits of conservation measures or ecological accomplishments by husbandry would help to promote their acceptance.

Finally, there is a demand for conceptions with which indicator-related ecological goods within entire environmental quality goals could be practically assessed economically and could be integrated into an on-farm market oriented rewarding system. It is being discussed at present whether rewarding farmers' ecological accomplishments should be integrated into agri-environmental programmes, taking into consideration market principles by trading with ecological goods as products, whose quality is described in detail by the suppliers as well as by the purchasers, and whose price can be defined as an indicator for the scarcity and need of each ecological good. In this respect the allocation of property rights to natural resources is estimated as fundamental. However, the demands and consensus within society will produce clearly defined rules for acting (Gerowitt et al., 2003).

5. Final remarks and conclusions

As can be concluded easily from the descriptions above, the intention of this volume is not a theoretical scientific discussion of terms, of biodiversity and of indicator concepts. Its goal is rather to elucidate the great range of facets and approaches with regard to questions on the development of and agreement on biotic indicator (systems), taking into special consideration the complex problems of their conversion into practice.

The term "indicator" implies in the principle the aspect of an application; i.e. something should be "indicated", from which actions are derived: a status, a process or a development in the past, at present or in the future. In this context it can be assumed that every scientist (even those conducting fundamental research) involved in the development and/or validation of an indicator will feel satisfied if "his/her" indicator or indicator system is included in a practical approach. Starting from this assumption, basically no great differences between the administrative requirements and the quality of indicators which have been developed according to scientific principles would be expected. Nevertheless, huge discrepancies between the expectations of administrative or practical institutions and scientific reality have to be admitted. Within this volume, particularly in sections "Requirements" and "Biodiversity and Habitat", these contrary expectations of political/administrative demands on the one hand and science on the other clash.

Undoubtedly, there are many highly sophisticated methods for indicating parameters (functional diversity, species diversity, habitat quality, etc.) related to several goals (environmental loads, conservation, biological control, etc.) which generally allow a gradual, very sensitive, but highly exact assessment of the actual status and/or of (future) developments in all habitat-related areas. Unfortunately, the great majority of all those advanced indicators needs to be assessed in each location specifically and requires too much labour and unaffordable skill levels, meaning that they are not practicable.

These discrepancies become particularly clear with regard to those indicators developed for habitat levels (see Büchs et al., 2003), which are connected very closely to pure scientific research due to their high

and gradual resolution of environmental aspects. Beside validations, baselines and reference values, the question of practicability and conversion is of central importance in the future. To be realistic (i.e. to meet practical demands in any way), conversion into practice would require a simplification of the indication procedure to such an extent that it would affect the scientific exactness significantly, meaning that such indicator models should be capable of allowing large tolerances and error rates. The synoptic introduction to each section provides suggestions to simplify the application of indicators in the sense described above, but due to the fact that costs and labour have to be reduced to a minimum and indicators have to be applicable to large areas and several regions, a normal scientific validation will obviously not possible. Similar to technical developments, only the experience of a broad application in practice will provide information in the long term on whether an indicators function is sufficient or not. Within such practical experience specific regional/local conditions possibly lead to opposing results which exclude ways of simplification in applying indicators. Therefore, striving for a scientific standard which is too high, and perfection in developing and validating indicator systems involves the risk of paralysing progress and causing contradictory effects with regard to the protection and maintenance of biodiversity.

It will be obvious that even this extensive portrayal cannot provide final or ideal solutions for the cardinal problem of indicator development and application. However, the intention is rather to convey awareness of and understanding for the difficulties of the different uses and purposes of biotic indicators by examining several facets and areas of unsolved problems, and to initiate a horizontal (concerning different subject areas and scientific areas) and vertical (concerning pure research, applied research, practical and administrative conversion and political decision makers) transdisciplinary discussion.

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